HIGH FREQUENCY SEMICONDUCTOR DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

Sub A1 The present invention relates to MMIC (Monolithic Microwave Integrated Circuit) having a wave guide for high-frequency signal transmission.

2. Description of the Related Art

Sub A2 Being different from conventional silicon integrated circuits, MMICs comprising high-speed semiconductor devices such as that represented by HEMT (High Electron Mobility Transistor) or HBT (Hetero Bipolar Transistor) necessarily include a wave guide as the inner transmission line for high-frequency signals. Micro-strip lines are generally used as the high-frequency signal wave guide, because of their stable line characteristics and low dispersion characteristics which means that the frequency dependency of propagation constant is weak.

FIG.1 shows an MMIC having conventional micro-strip lines, in particular, a three-dimensional MMIC having micro-strip lines composed of multi-layered line conductors.

Sub A3 As shown in FIG.1, the MMIC having a conventional multi-layered structure includes ground plate 3 formed on the semiconductor substrate 1 with the insertion of surface insulation film 2 therebetween, and ground plate 3 forms micro-strip lines together with line conductors 5 each formed on each of interlayer insulation films 4, respectively. In addition to line conductors 5, pad 6 for the external connection is provided on the most upper interlayer insulation film 4.

The MMIC having multi-layered high-frequency micro-strip lines as explained with reference to FIG.1 features that it is suited to high density integration, compared to MMICs having line conductors disposed in a single layer.

However, none of reports appear to discuss the reliability of such multi-layered high-frequency micro-strip lines so far.

SUMMARY OF THE INVENTION

Sub A4

It is an object of the present invention to provide a structure of three-dimensional MMIC designed by taking reliability into consideration.

In three-dimensional MMICs, the interlayer insulation films are composed of a resin (organic) insulating material such as polyimide or benzocyclobutene (BCB).

Sub A5

The interlayer insulation film of such resin insulating material is relatively soft and is apt to deform, when a pressure is applied thereto. Pads, for instance, are subjected to a mechanical shock by the tip of a bonding tool during wire bonding thereto, and deformation is caused in the interlayer insulation film around there.

As a result, line conductor 5 on the most upper interlayer insulation film would peel off or bends. When wire bonding is over and application of the pressure by the bonding tool is removed, the interlayer insulation film can recover from the deformation itself. However, the line conductor that is once peeled off or bent cannot restore, and results in the change of its high-frequency transmission characteristics.

In the present invention, a groove is provided in the interlayer insulation film adjacent to the pad, for relaxing the influence of the deformation given during wire bonding processes.

Sub A6

FIG.2 shows the essential concept of the present inveniton. As shown in the drawing, groove 7 is provided adjacent to pad 6, and thus, PAD REGION and WIRING REGION are physically separated each other at least by the groove near the respective surfaces thereof. Accordingly, even when pad 6 is subjected to wire bonding processes, aforesaid deformation caused in the interlayer insulation film by the pressure applied to pad 6 is relaxed by the shape effect of groove 7, and the influence of the deformation on WIRING REGION can be alleviated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 is a cross-sectional view of an MMIC having conventional micro-strip lines;

FIG.2 is a cross-sectional view for explaining the essential concept of the present inveniton;

FIG.3 is a plan view showing an embodiment of the present inveniton;

FIG.4 is a cross-sectional view taken on segment line A-A' in FIG.3;

FIG.5 is a plan view showing another embodiment of the present inveniton;

FIG.6 is a plan view showing futher another embodiment of the present inveniton; and

FIG.7 is a plan view showing still another embodiment of the present inveniton.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention will be explained in the following with reference to drawings.

FIG.3 is a plan view of an embodiment of three-dimensional MMIC according to the present inveniton, and FIG.4 is a cross-sectional view taken on segment line A-A' in FIG.3.

In this embodiment, a compound semiconductor substrate of GaAs is used, in which active devices such as FETs are formed, and a surface insulation film 2 of silicon nitride, for instance, is formed on the surface of the substrate. A ground plate 3 to be connected to ground potential is formed on the surface insulation film 2, and a plurality of interlayer insulation films 4 are formed thereon. The interlayer insulation films are composed of polyimide or benzocyclobutene (BCB). On interlayer insulation films 4, line conductors 5 each having a predetermined pattern are formed, respectively. Each of line conductors 5 is formed from gold (Au) by using sputtering or vacuum deposition and patterned by using ion milling or lift-off technologies.

In this embodiment, groove 7 is formed to surround pad 6, except the side of pad 6, which is facing the edge of semiconductor substrate 1. Groove 7 is formed by using methods like etching. The depth of groove 7 can substantially be optional, such as that the same as the thickness of one of the interlayer insulation films, or deeper or shallower in terms of the

thickness. In this embodiment, groove 7 is formed to extend into plural interlayer insulation films 4.

Pad 6 is formed in the same process as that for line conductor 5 on the most upper interlayer insulation film 4, and is connected via through hole 8 to another line conductor 5 extending immediately thereunder, to be used for internally supplying a potential.

According to this embodiment, the deformation caused in the interlayer insulation film during the wire bonding to pad 6 is relaxed by groove 7, and line conductor 5 on the most upper interlayer insulation film 4 can be prevented from peeling off or bending of itself.

In this embodiment, pad 6 is formed adjacent to the edge of the semiconductor substrate chip, and groove 7 is not provided at the periphery of the semiconductor substrate chip where none of line conductors is provided. However, groove 7 may be provided along whole of the periphery, according to need.

FIG.5 is a plan view for explaining another embodiment of the present inveniton. In this embodiment, line conductor 5 is provided on the most upper interlayer insulation film on which pad 6 is provided, and is connected to pad 6, as shown in the drawing. Accordingly, a connection portion 9 where groove 7 is not formed is provided for allowing line conductor 5 to pass therethrough.

Also in this embodiment, the deformation of the interlayer insulation film caused by bonding pressure to pad 6 is relaxed by groove 7, and the shape change which would propagate into WIRING REGION can be reduced. A portion of PAD REGION is connected with WIRING REGION through connection region 9. However, the deformation by the bonding pressure applied to pad 6 is almost interrupted by the discontinuity provided in the interlayer insulation films by groove 7, and accordingly, line conductor 5 connected to pad 6 is hardly affected by the influence of the deformation.

FIG.6 is a plan view for explaining futher another embodiment of the present inveniton. In this embodiment, plural grooves 7 are provided. Also in this embodiment, the

deformation by the bonding pressure is relaxed by grooves 7 as in the previous embodiments, and the change in the shape of the insulation film in WIRING REGION is reduced.

FIG.7 is a plan view for explaining still another embodiment of the present inveniton. The structure employed in this embodiment is that a ring-shaped groove 7 is provided between a region for forming pads 6 and a region for forming line conductors (not shown) on semiconductor chip 100.

Each of pads 6 itself is solid because of its larger area compared with line conductors, and hardly peel off or deform, even if deformation is caused at a pad 6 during bonding process and reaches neibhoring pads 6.

In this embodiment, the groove has a rectangular shape in its plan view, however, there is no particular limitation in the shape of the groove, as far as it is intended to provied a discontinuity at least in the most upper interlayer insulation film. And also, there is no particular limitation in the depth and the shape of the bottom of the groove (e.g. a groove having U- or V-shaped cross-section).

According to the present invention, as explained above, the deformation caused in the interlayer insulation film during bonding process hardly propagate into WIRING REGION, and line conductors on the most upper interlayer insulation film can be prevented from their peeling off from the interlayer insulation film and the change in their high-frequency transmission characteristics.